Marine Sciences and Technology

Faculty and Fields of Interest

Altabet, Mark A Professor of Marine Science and Technology (1995), BS 1979 State University of New York at Stony Brook, PhD 1984 Harvard University. *Specializations:* Marine and environmental chemistry.

Brown, Wendell S (Chairperson, Department of Estuarine and Ocean Sciences) Professor of Marine Science and Technology (2000), BS 1965, MS 1967 Brown University, PhD 1971 Massachusetts Institute of Technology. *Specializations:* Coastal physical oceanography, moored ocean observations, real time circulation modeling and data/information management system development.

Chen, Changsheng Professor of Marine Science and Technology (2001), BS 1979, MS 1983 Ocean University of Qingdao, China, MS 1989, PhD 1992 Massachusetts Institute of Technology/Woods Hole Oceanographic Institute. *Specializations:* Modeling and observational exploration of coastal ocean circulation, oceanic frontal processes, turbulent mixing/bottom boundary layer dynamics, chaotic mixing, western boundary currents, internal waves and tides, and biological/physical interaction.

Goodman, Louis Professor of Marine Science and Technology (2001), BS 1967, MS 1969, PhD 1971 Drexel University. *Specializations:* physical oceanography, ocean internal waves, turbulence and mixing, bottom and surface mixed layers, ocean acoustics, autonomous underwater vehicles.

Howes, Brian Professor of Marine Science and Technology (2000), BA 1974 Rutgers University, MA 1980, PhD 1984 Boston University. *Specializations:* Estuarine and embayment nutrient cycling and modeling; saltwater and freshwater wetland, lake, embayment management and restoration.

MacDonald, Daniel Assistant Professor of Marine Science and Technology (2003) BSCE 1992 University of New Hampshire, MS 1996 Cornell University, PhD 2002 Massachusetts Institute of Technology/Woods Hole Oceanographic Institute Joint Program. *Specializations:* Estuarine oceanography, hydrodynamics, stratified turbulence, environmental engineering.

Rothschild, Brian (Dean, School of Marine Science and Technology) Professor of Biology (1995), BS 1957 Rutgers University, MS 1959 University of Maine, PhD 1962 Cornell University. *Specialization:* Ocean ecosystems; *Current research:* Marine fish population dynamics, models of plankton dynamics and interactions.

Stokesbury, Kevin (Chairperson, Department of Fisheries Occeanography) Associate Professor of Marine Science and Technology (2000), BSc 1984, MSc 1987 Acadia University, Nova Scotia, PhD 1994 Universite Laval, Quebec. *Specializations:* Marine biology/ecology focusing on fisheries including scallop population dynamics and life history studies.

Sundermeyer, Miles Assistant Professor of Marine Science and Technology (2001), BA 1991 University of California, ScM 1995, PhD 1998 Massachusetts Institute of Technology. *Specializations:* Dispersion and transport processes, numerical modeling of mixing and stirring, numerical modeling of physical and biological interactions.

Faculty with SMAST Joint Appointments

Bisagni, James J Associate Professor of Physics and Marine Science and Technology (1997), BS 1972 University of New York at Stony Brook, MS 1976, PhD 1991 University of Rhode Island Graduate School of Oceanography. *Specializations:* Physical oceanography, satellite oceanography.

Buck, John R Associate Professor of Electrical and Computer Engineering and Marine Science and Technology (1996), SB 1989, SM 1991, PhD 1996 Massachusetts Institute of Technology. *Specializations:* Underwater acoustics, signal processing, marine mammal bioacoustics.

Eberback, Eugene Associate Professor of Computer and Information Science and Marine Science and Technology (2000), MS 1977, PhD 1982 Technical University of Warsaw. *Specializations:* Concurrent computations, artificial intelligence, evolutionary computations.

Fain, Gilbert Chancellor Professor of Electrical and Computer Engineering and Marine Science and Technology (1968), BSEE 1958, MSEE 1961, PhD 1967 University of Rhode Island. *Specializations:* Ocean systems, instrumentation and measurement systems, underwater acoustics, active circuits.

Friedman, Peter D Assistant Professor of Mechanical Engineering and Marine Science and Technology (2002), BS 1984 Georgia Institute of Technology, MS 1991 Georgia Institute of Technology, PhD 2001 Johns Hopkins University. *Specializations:* Experimental fluid mechanics and heat transfer, thermodynamics, nuclear power plant operation.

Georgianna, Daniel L Chancellor Professor of Economics and Marine Science and Technology (1978), BS 1965 College of the Holy Cross, PhD 1977 University of Massachusetts Amherst. *Specializations:* Marine resource economics, comparative economic systems, and economic history.

Gangopadhyay, Avijit Associate Professor of Physics and Marine Science and Technology, BTech 1979 Indian Institute of Technology, Kharagpur, MTech 1982 Indian Institute of Technology, New Delhi, PhD 1990 University of Rhode Island. *Specializations:* Physical oceanography, numerical modeling, climate studies.

O'Connor, Nancy J Associate Professor of Biology and Marine Science and Technology (1993), BS 1980 Southeastern Massachusetts University (UMass Dartmouth), MS 1982 University of Delaware, PhD 1990 North Carolina State University. *Specialization:* Marine invertebrate ecology.

Singh, Bal-Ram Professor of Chemistry and Biochemistry and Marine Science and Technology (1990), BSc 1977 Kamla Nehru Institute of Science and Technology, MSc 1979, MPhil 1982 Jawaharlal Nehru University, PhD 1987 Texas Tech University. *Specialization:* Physical biochemistry.

Tandon, Amit Assistant Professor of Physics and Marine Science and Technology (1999), BTech 1987 Indian Institute of Technology, PhD 1992 Cornell University. *Specializations:* Fluid dynamics, physical oceanography, environmental and computational physics.

Turner, Jefferson Chancellor Professor of Biology and Marine Science and Technology (1979), BS 1969 Guilford College, MA 1972 University of South Florida, PhD 1977 Texas A&M University. *Specialization:* Biological oceanography.

Zuo, Yuegang Assistant Professor of Chemistry [delete "/Biochemistry"] and Marine Science and Technology (1999), BS 1982 Wuhan University, China, MS 1984 Chinese Academy of Science, PhD 1992 Swiss Federal Institute of Technology. *Specializations:* Analytical chemistry, environmental chemistry, marine chemistry, photochemistry.

School for Marine Sciences and Technology at UMass Dartmouth

Degree Programs

Graduate students who enroll in the School for Marine Science and Technology (SMAST) at UMass Dartmouth access MS and PhD degrees which are offered through the University of Massachusetts Intercampus Graduate School of Marine Sciences and Technology (IGS).

The IGS is an administrative umbrella for the multi-campus faculty, who have diverse teaching and research interests in the marine sciences and associated technologies. The IGS faculty are distributed among four campuses—UMass Amherst, UMass Boston, UMass Dartmouth, and UMass Lowell. The IGS offers students advanced academic studies and research in a range of specializations clustered in five option areas.

SMAST is a major center for teaching, research, and economic development for UMass Dartmouth and the University of Massachusetts. Its faculty and staff engage in basic and applied research in areas that foster interactions with industries and public agencies on economic development and environmental and marine resource policy issues. While SMAST research tends to concentrate on the regional coastal ocean estuaries and watersheds of Massachusetts, New England and the adjacent U.S., a number of programs are focused in remote regions of the global ocean.

SMAST is located on 2.6 acres in south New Bedford along Clark's Cove and Buzzards Bay.

IGS offers both Master of Science degree and Doctor of Philosophy degree programs in marine sciences and technology. Students graduating with a MS or PhD degree from IGS receive a joint degree from the University of Massachusetts Amherst, Boston, Dartmouth, and Lowell. The degree programs are fundamentally grounded in a broad, integrated, interdisciplinary approach to the study of marine sciences and technology.

Students located at the four participating campuses complete (1) required core courses selected from the natural and social sciences to equip them for interdisciplinary studies and research and (2) elective courses in a chosen area of concentration. The programs prepare students for employment opportunities in the private and governmental sectors and academia. Emphasis is placed on educating researchers and scholars who will contribute not only to basic research but also to the application of that research in a coherent approach to resource management and economic development issues.

Admission Standards

Successful applicants will generally have completed an undergraduate or graduate degree with a GPA of 3.00 or better and will have an undergraduate major in one of the basic scientific disciplines or engineering, or will have strong multidisciplinary training with completion of at least six semesters of coursework in the natural sciences, generally to include biology, chemistry, and/or physics. Preparation in mathematics at least through integral calculus is strongly encouraged. Students who do not meet these criteria need to identify a faculty advocate who must bring a request for exception before the Admissions Committee. At the discretion of the Admissions Committee applicants may make up deficiencies in prior coursework either before or after admission is granted to the IGS. Consideration will be on a case-by-case basis, and the recommendation of the committee will be forwarded to the Dean for approval.

Candidates may apply for admission at either the masters or doctoral level. Students admitted directly into the doctoral program are expected to have exceptional academic credentials and/or work experience. Students entering with a bachelor's degree may be required to complete the requirements of a masters degree before admission to the doctoral program. Students entering with a masters can be admitted at the doctoral level provided the degree, coursework, and research experience warrant such a decision by the Admissions Committee.

Application Criteria

The Admissions Committee will evaluate a number of additional criteria in its consideration of applications. They include performance on the Graduate Record Examinations (GREs) and TOEFL (if appropriate), three letters of recommendation, transcripts, and statement of interest and intent. Successful applicants will generally have combined verbal and quantitative GRE scores greater than or equal to 1200, and a strong analytical score. International students must take the Test of English as a Foreign Language (TOEFL). A minimum of 600 (or 213 on the computer-based exam) is strongly recommended. GRE Subject tests may also be used in evaluation but are not required.

Three letters of recommendation from referees familiar with the applicant's academic and/or work experience are required.

Official transcripts of all undergraduate and graduate coursework must be submitted.

Statements of Interest and Intent are also requested.

- The Statement of Interest should provide reviewers an indication of the motivation of the student for pursuing graduate work.
- The Statement of Intent should describe how graduate training would address the student's career goals.

The applicant is strongly encouraged to identify one or more faculty members who could serve as the applicant's advisor, at least initially, upon admission. To this end, discussions with individual faculty before completing the application are strongly encouraged.

Registration Across Campuses

Courses may be taken at any IGS-affiliated program on the four campuses, in other departments at UMass Dartmouth, or at other area oceanographic institutions, and may be included in a student's program of studies subject to approval by the student's major advisor and/or dissertation committee.

UMass campuses collaborate to permit joint-program students, like those in the IGS, at one campus to take courses at another with a minimum of effort. In brief, UMass Dartmouth IGS students go to our Registrar's Office to register and pay for a course offered at another campus (offered either on that campus or by distance learning). That campus provides

evidence of course completion, and grades as well as credit are shown on the UMass Dartmouth transcript.

Graduate Assistantships and Financial Aid

Financial assistance is available to full-time graduate students on a competitive basis. Requests for financial assistance should be made on the admission application.

For information about loans or other assistance, please consult the chapter on "Expenses and Financial Assistance."

Contact

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The MS program requires a minimum of 30 credit hours with the thesis option and 33 credit hours with the non-thesis option. Students are required to take core oceanography courses (two for MS; three for PhD) and a policy course, and choose additional courses appropriate to a selected option area. Attendance at a weekly seminar series is required (1 credit per semester for two semesters) for first-year students, and each student must present at least one seminar in their third or fourth semester. Full time MS students can complete their degree requirements in two years.

Core Course Requirements

Each IGS student must complete two (MS) or three (PhD) oceanography core courses in biological, chemical, and physical oceanography. A course in marine policy and/or management areas (including law and economics) and a course covering technology or quantitative skill are also required. The core courses (listed on the IGS website at www.umassmarine.net) are intended to provide a common grounding in the biological, chemical, and physical oceanographic areas of marine sciences and technology, and in related marine policy and management disciplines. Courses covering technology and quantitative skills are generally subject to student choice and guidance committee approval, though there may be requirements specific to each option area. At least two core courses are offered each semester. Students normally complete the core courses in the first two semesters.

Successful performance in the core courses is required for advancement to degree status. A grade of B or better in each core course and an overall average of 3.0 in the core courses are required. There is a retake option on a course for which the student receives a grade of B- or less.

Option Areas and Electives

Each IGS student selects one of several option areas. Each option area includes several marine policy or management core courses and electives appropriate to that area. The stuent approves a sub-set of those courses as approved by their faculty advisor and/or thesis committee. Descriptions of the option areas, as well as lists of the electives associated with each concentration may be found on the website at www.umassmarine.net.

Students typically take most of their elective courses on the campus where they and their major faculty advisor are in residence. Some elective courses, however, may be taught via distance learning. In addition, students may choose to take courses at a different campus for a period of time during their course of study in order to access certain topics or to take advantage of research opportunities.

Thesis and Non-Thesis Options

Most SMAST MS students choose to do a thesis and are assigned a Thesis Committee, chaired by the student's major advisor. The advisor ensures that the student fulfills all requirements of the IGS as well as other campus requirements, including a public lecture on the student's thesis. Each student electing the non-thesis option, in addition to an additional 3 credits, must complete a substantial research paper that must be read and approved by the major advisor and at least one other faculty member.

Thesis students must register for thesis research each semester after completing formal coursework, until they complete their degree.

Sequence of Courses by Semester

In the first two semesters, fulltime MS students normally complete the core courses, the seminar requirement, and an elective or two. Additional coursework and the thesis or the non-thesis research paper are typically completed in the third and fourth semesters.

Additional Course Requirements for PhD Students

PhD degree students complete the same courses as do MS students, as listed above, with modifications to those requirements as indicated in patenthetical annotations. The PhD students normally take the four required courses in their first year. Work in the option area usually includes at least an additional 24 credit hours of courses, which help the student prepare for the written and oral parts of a general examination.

PhD Candidacy Examinations and Dissertation

No later than the sixth semester, the student's committee administers the written and oral candidacy examinations. The candidacy

examinations are comprehensive and cover the core areas and the student's area of concentration. They are designed to test the intellectual competence and maturity of the student in the broad area of marine sciences and technology and in the selected area of concentration.

A scholarly dissertation based on original research is required of all PhD candidates. Dissertation research may be done in the laboratory or the field, or may be carried out in part during residence with an appropriate private business or government agency. Presentation and defense of a satisfactory dissertation, normally to be completed within five years from the date of advancement to candidacy, fulfill the degree requirements. The dissertation defense consists of a public lecture on the dissertation and a subsequent oral examination by the candidate's dissertation committee.

Students must register for dissertation research each semester after completing formal coursework, until they complete their degree.

MAR 510 three credits
Introductory Chemical Oceanography
Prerequisite: Enrollment in IGS or permission of instructor
Chemical oceanography starting with the basic chemical and physical properties of sea water and going through the major processes shaping chemical distributions in the ocean. A brief review of basic thermodynamics and chemical equilibria precedes a discussion of carbonate equilibria and trace metal speciation. Throughout much of the course an interdisciplinary approach is taken and pertinent material on the interaction between ocean chemistry and marine physics, biology, and geology will be presented. Whenever possible, the results of recent studies will be incorporated into class material and the last few class periods are devoted to special topics.

MAR 520 two credits
Thesis Proposal Development Seminar
Guides graduate student preparation of an acceptable master's thesis or PhD dissertation proposal in a series of papers and in-class oral presentations. Students work with a thesis advisor and committee within a framework defined by the instructor to define a thesis problem in terms of relevant literature and design a research plan, including a support budget. In the process, students are expected to improve their skills in literature research, writing, and oral presentations.

MAR 540 three credits
Introductory Fisheries Science
Provides a background on the development of fisheries science and examines the theories and techniques of biology, ecology, oceanography, and population dynamics presently employed. Components include fish and shellfish basic population dynamics, early life history recruitment, migration, growth, fishery dependent/independent surveys, alternative abundance measurement techniques, habitat considerations, and introductory fisheries modeling.

MAR 545 (BIO 545) four credits
Biological Oceanography
Three hour lecture, three hour laboratory
Prerequisite: BIO 316 or equivalent, or permission of instructor
The cycle of productivity in the marine environment and the physiological and morphological adaptations of plant, animal and bacterial populations within various oceanic regions. Interrelationships of the plankton, the nekton, and the benthos are stressed.

MAR 555 three credits
Introductory Physical Oceanography
Prerequisite: Permission of instructor
A descriptive treatment of ocean atmosphere interactions, water properties, general wind driven and thermohaline circulation, waves and tides, and coastal processes. Simplified conceptual models demonstrate the important principles.

MAR 560 three credits
Acoustical Oceanography
Prerequisite: Basic calculus and physics courses
Modern methods of acoustics in oceanography and the use of acoustics in other subdisciplines of the marine sciences emphasizing fundamental theories of relevance to the ocean. The course introduces students to the fundamental nature of wave propagation, the concept of acoustic impedance, sources of sound, array theory, and duct propagation. Students apply sonar equations to both passive and active acoustics. Reverberation, scattering, deep and shallow propagation are discussed. Students examine tools and techniques used in modern acoustical oceanography, including acoustical tomography, propagation through ocean internal waves, fisheries acoustics, and Doppler techniques.

MAR 572 three credits
Marine Resource Economics
Prerequisites: Graduate standing and consent of instructor (for economics undergraduates prerequisite is ECO 472)
Application of economic reasoning to understanding causes and solutions of problems faced in managing the marine environment. Students learn to analyze natural resources management issues from an economic perspective with emphasis on management of marine fisheries. Students learn how economists determine the value of environmental goods and services that are not traded in markets and about economic policy tools used to address problems such as marine pollution and other threats to the marine environment.

MAR 596 three credits
Directed Study
Prerequisite: Permission of the instructor, the SMAST Graduate Program Director, and the department chairperson.
Allows completion of a numbered course formally in the graduate program listing but not being offered as a scheduled class.

MAR 599 three credits
Special Topics in Marine Sciences and Technology
Prerequisites: Variable, depending on topic
An advanced treatment of a special topic in specific areas of marine sciences and technol-

ogy with an emphasis on recent developments. The subject matter varies according to the interests of the instructor and the students.

MAR 600 up to 6 credits
Masters Thesis Research
Prerequisite: Graduate Standing and approval of student's Graduate Committee
Thesis research on an experimental or theoretical project in Marine Science or Technology under a faculty advisor.

MAR 603 variable credits
Pre-Dissertation Research
Research for and preparation of doctoral dissertation proposal. The dissertation proposal must provide a thorough survey of the research activities in the research topic area and it must present original and innovative research ideas and preliminary results as well as a defined research scope and directions. PhD students must have passed this course before registering for doctoral dissertation research credits. Graded P/F.

MAR 610 three credits
Ocean Turbulence
3 hours lecture
Prerequisite: MAR 555; introductory fluid dynamics; or permission of instructor
Ocean turbulence as a factor in mixing the ocean that is critical for understanding the physical, chemical, geological, and biological processes in the ocean. The basics of fluid dynamics that underpin turbulence theory are reviewed, followed by a consideration of classical turbulence theory and its application to ocean processes. Emphasis is placed on both a mathematical as well as a physical understanding of turbulence. The treatment includes the use of random variables, dimensional scaling, and the introduction of non-dimensional quantities such as the Reynolds, Richardson, and Prandtl numbers. Turbulent energy exchange between the mean flow and turbulent field and turbulent diffusion are discussed. Observations of turbulence and modern data analysis techniques are discussed.

MAR 615 three credits
Dynamics of Estuarine Circulation
Prerequisite: Permission of instructor
Physical processes governing estuarine circulation. Topics include estuarine classification, tides in estuaries, turbulence and mixing in stratified environments, secondary (cross-channel) flows, salt and momentum balances, velocity-induced straining, hydraulic control and the establishment of estuarine fronts, engineered discharges and plumes, and other types of flows important to estuaries. The course will make ample use of homework assignments and problem solving, with examples from the appropriate scientific literature.

MAR 620 four credits
Case Studies in Estuarine Dynamics
3 hours lecture, 3 hours laboratory
Prerequisite: Permission of instructor
Interdisciplinary estuarine dynamics emphasizing how interactions between physical, biological, and chemical phenomena govern major estuarine processes. The course uses two estuaries as case studies of the types of interdisciplinary problems encountered in marine ecosystems with partial focus on temperate estuarine environments. The two case studies are used to compare and contrast physical, biological, and chemical characterization of estuaries of differing watersheds, tidal dynamics, and geomorphologies. Field and laboratory studies are used to complement the theory taught in lectures and serve as a "hands on" part of the course.

MAR 622 three credits
Case Studies in Fisheries Science and Management
Prerequisite: Permission of instructor
Integration of fundamental concepts of natural science and social science relating to management of living marine resources. This course utilizes a case study of a fishery to explore how knowledge and methods from a variety of disciplines including oceanography, biology, ecology, mathematics, and economics are used together in management of marine fisheries.

MAR 630 three credits
Estuarine Biogeochemistry
Prerequisites:: Biogeochemistry or microbiology and biological oceanography or permission of instructor
Biogeochemistry of estuaries emphasizing complex interactions of the major geochemical cycles and biological systems such as animal and plant production, nutrient uptake, and marine system transformations. Among the topics covered are the basic biogeochemical cycles as they related to both the productivity and function of estuarine systems, and the role of estuaries within the coastal zone relative to their watersheds and adjacent off shore waters. Estuaries are examined both within the global and the New England context. Current issues of estuarine management and restoration are addressed.

MAR 640 three credits
Global Marine Biogeochemistry
Prerequisite: MAR 510
Advanced treatment of marine biogeochemistry and global environmental change. The oceans play a predominant role in global environmental change particularly with respect to their major geochemical cycles of carbon, nitrogen, oxygen, phosphorus, sulfur, etc. The major features of these cycles as they operate on a global basis are presented. Examples of natural and anthropogenic perturbations at present and in the past are a major focus of this course. A significant segment of the material deals directly with the role of oceans in controlling atmospheric carbon dioxide through its biological and solubility pumps.

MAR 650 four credits
Marine Ecosystem Dynamics Modeling
Prerequisites: IGS core courses, preparation in calculus and partial differential equations, or permission of instructor
3 hours lecture, 2 hours laboratory
Structures and dynamics of ocean ecosystems. The dynamics of global to local scale biophysical interaction processes are explored in terms of basic dynamic principles. Existing ecosystem models are used to solve some realistic coastal ecosystem problems. There is a strong emphasis on solving process oriented problems requiring integration of lecture materials. A term paper is required.

MAR 660 three credits
Coastal Physical Oceanography
Prerequisite: Permission of instructor
Physics of the coastal ocean covering a wide variety of coastal physical oceanographic processes with emphasis on the continental shelf processes. Topics include tides and tidal currents, upwelling and downwelling, front processes, fresh water plumes, coastally trapped waves, boundary layer flows, and vertical and horizontal dispersion processes. This course is intended for students in IGS who require a working understanding of coastal ocean circulation and dynamics. Students enrolling in this course should be thoroughly comfortable with differential and integral calculus.

MAR 665 three credits
Numerical Methods in Ocean Sciences
Prerequisites: Partial differential equations, or permission of instructor
3 hours lecture
The basic concept of finite-difference, finite-element, and finite-volume methods, the various numerical methods used in solving the advection, diffusion, and elliptical equations, numerical instability, open boundary conditions, and numerical solutions of the primitive equations.

MAR 670 four credits
Advanced Time Series Analysis of Ocean

and Earth System Data
Prerequisites: College calculus and introductory statistical methods
Advanced statistical tools are used to analyze ocean and earth system time series with specific application to fixed location oceanographic and meteorological data sets. Lectures describe the theoretical aspects of the advanced statistical tools that are used to analyze discrete data sets. Students use practical analysis exercises to learn the various ways to interpret set of equally spaced time and or space data series in the context of instrumental and statistical noise.

MAR 700 one credit
SMAST Seminar in Marine Science and Technology
Prerequisite: Graduate standing
Seminar discussions and presentations based on research or detailed literature surveys.

MAR 701 variable credit
Doctoral Dissertation Research
Prerequisites: Successful completion of PhD comprehensive examination and approval of doctoral dissertation proposal by the student's graduate committee
Investigations of a fundamental and/or applied nature representing an original contribution to the scholarly research literature of the field. PhD dissertations are often published in refereed journals or presented at major conferences. A written dissertation must be completed in accordance with the rules of the Graduate School and the School for Marine Science and Technology. Admission to the course is based on successful completion of the PhD comprehensive examination and submission of a formal proposal endorsed by the student's graduate committee and submitted to the SMAST Graduate Program Director.

MAR 730 three credits
Biological Oceanographic Processes
Introduction to the processes controlling phytoplankton, zooplankton, heterotrophic bacterial and benthic infaunal growth and abundance. Includes broad-scale survey of patterns of productivity and abundance in the coastal zones, upwelling centers, gyres, and the deep sea, and brief survey of ecosystem simulation models. Readings from the primary literature. Anthropogenic effects on marine communities will be stressed. Calculus will be used throughout the course. This course is taught at UMass Boston.